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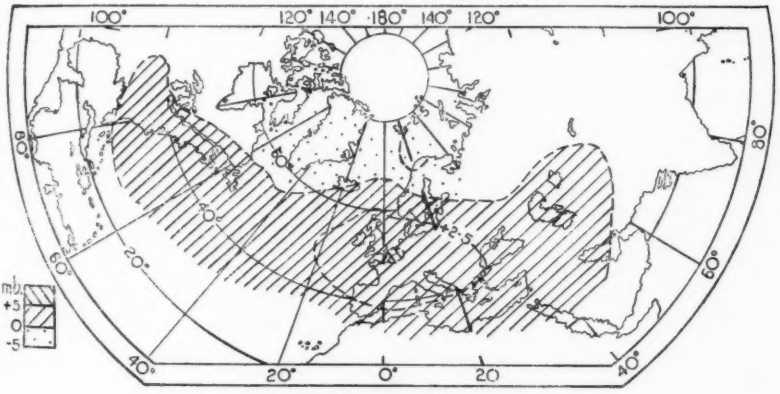
RECENT LONG PERIOD WITH PRESSURE ABOVE NORMAL OVER EUROPE AND THE NORTH ATLANTIC

By E. V. NEWNHAM, B.Sc.

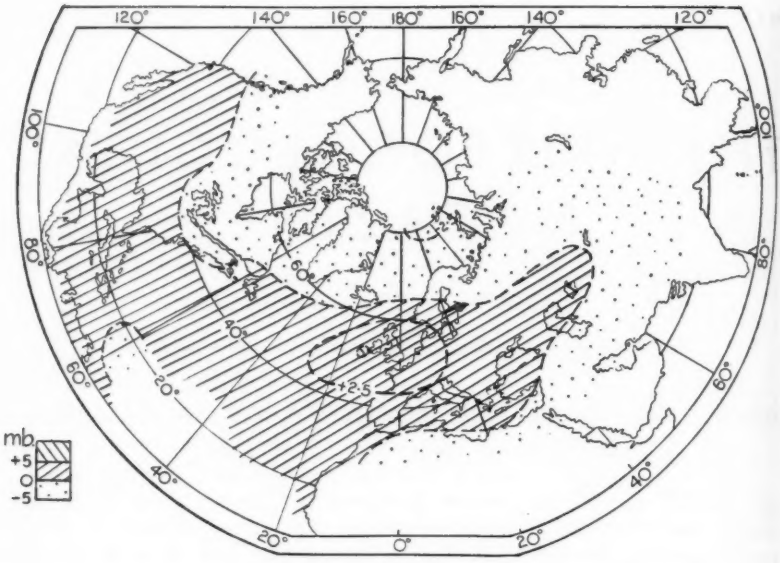
Fig. 1 shows isopleths of pressure for intervals of 2·5 mb. for the period October 1948–September 1949. They indicate an area with pressure above normal extending from the Mississippi to central Asia, with an excess of more than 2·5 mb. in an area centred over Belgium, and covering about 50 degrees of longitude and 20 degrees of latitude. Over part of south-east England, northern France, Belgium and Holland the excess was about 5 mb. Examination



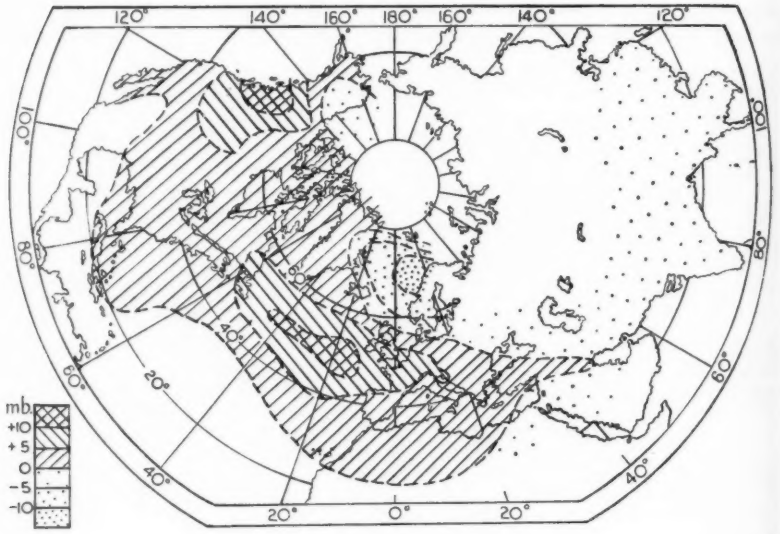
October 1948–September 1949

FIG. 1—PRESSURE ANOMALIES

of the monthly maps of pressure anomaly for the period 1873–1941, prepared by Dr. C. E. P. Brooks, showed only one period (February–December 1921) with pressure anomaly roughly comparable in size and duration, but in 1921 there was no succession of months with closely similar anomaly such as the four months January–April 1949 (Figs. 2–4); moreover there is no such period in all the 69 years, instances of even two successive similar monthly



February–December 1921

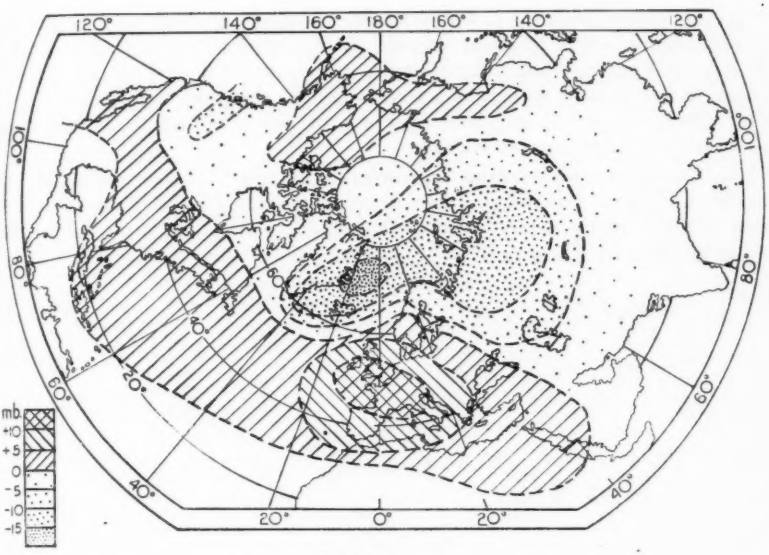


January 1949

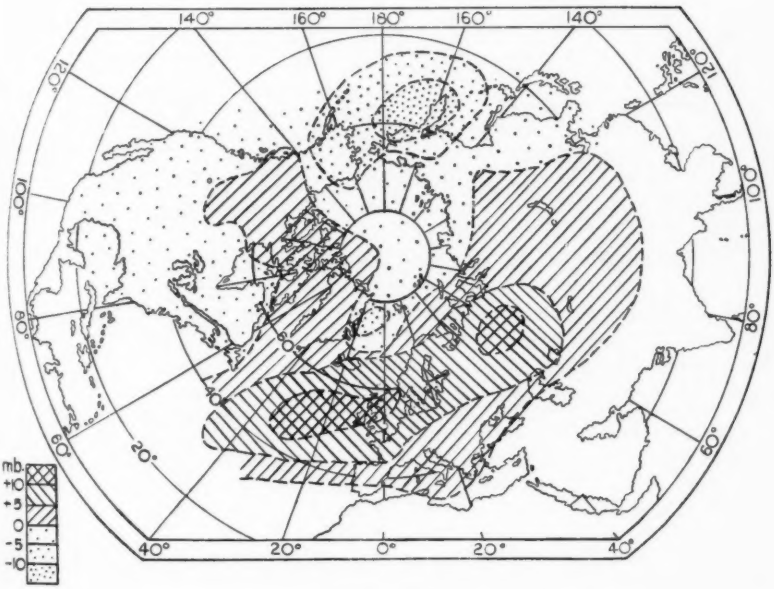
FIG. 2—PRESSURE ANOMALIES

maps being very uncommon. It appears, therefore, that there was in 1949 a general disturbance of the normal distribution of pressure over the northern hemisphere of unique persistence.

The following are the most noteworthy long periods with mean pressure above normal in addition to October 1948–September 1949:—



February 1949

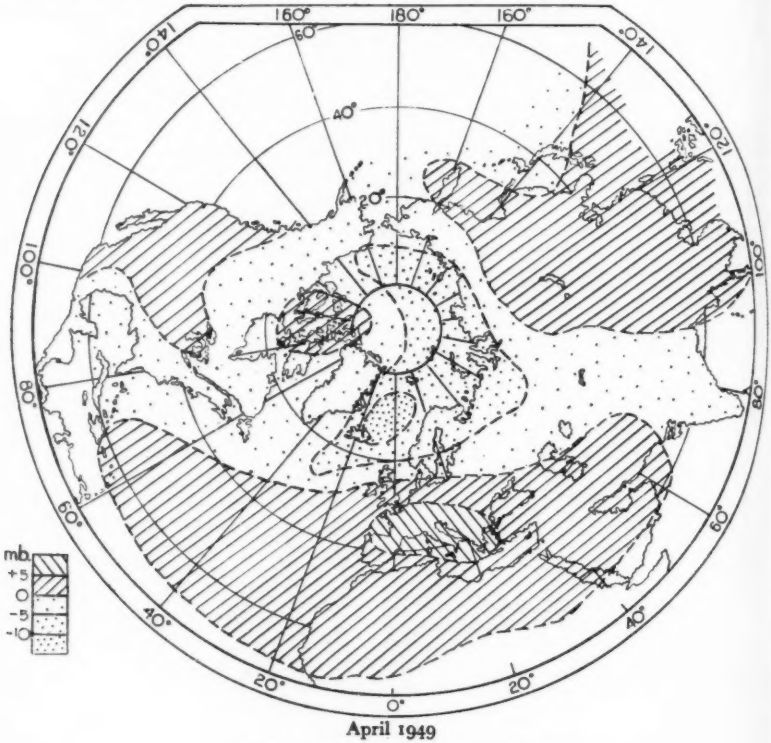


March 1949

FIG. 3—PRESSURE ANOMALIES

(*a*) From October 1883 to January 1884 pressure was above normal over the North Atlantic south of about latitude 60°N., and over southern and central Europe, the excess being a little over 4 mb. over the Bay of Biscay. After a break of five months there was a second period, this time lasting five months (July–November 1884) with pressure 3 or 4 mb. above normal over Europe and at least the western parts of Russia.

(*b*) During the six months September 1904–February 1905 pressure was above normal over Persia, the Mediterranean, southern and central Europe, and over the North Atlantic to about longitude 30°W., the excess being nearly 4 mb. in northern France.



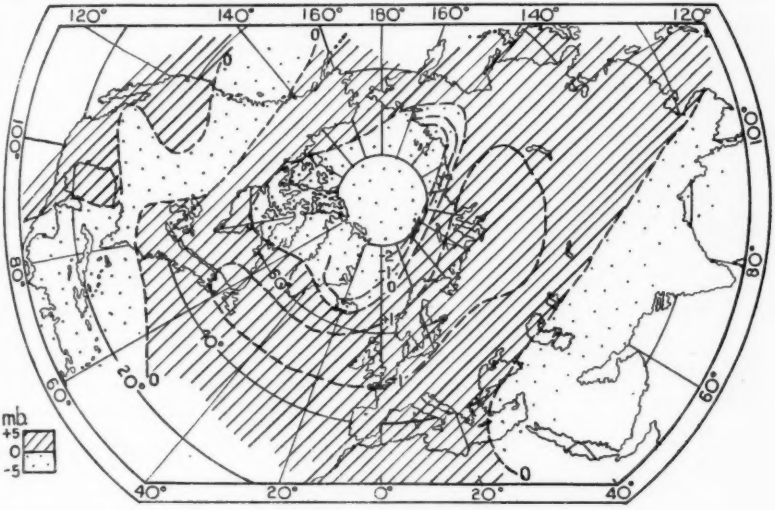
April 1949

FIG. 4—PRESSURE ANOMALIES

(*c*) From February to December 1921 pressure was above normal from central Asia westwards at least so far as the Pacific coast of the United States of America (see Fig. 2). The region with excess of more than 2·5 mb. was rather smaller than in 1948–49, and lay about 10 degrees further west, and the only region where the excess may have reached 5 mb. was a small one west or south-west of Valentia. As has already been mentioned this period is comparable in some ways to 1948–49.

(*d*) A rather different type of excess pressure is that of the much longer period (25 months) from November 1932 to November 1934. This is shown

in Fig. 5, the isallobars being for intervals of 1 mb. The excess was smaller than for the shorter periods dealt with so far, but was nearly 2 mb. over a large area in northern Russia and the north-west of Siberia. It can be seen that the area with pressure above normal was very large, including the North Atlantic, Europe and a large part of Asia.



November 1932–November 1934
FIG. 5—PRESSURE ANOMALIES

(*e*) The last period which deserves mention is the nine months February–October 1939. Pressure was above normal from northern Asia across Europe and the North Atlantic to north-east Canada, and almost to the east coast of the United States. The excess was more than 2·5 mb. in Sweden, northern Norway and Finland, but was less than 1 mb. over most of the region.

DIURNAL VARIATION OF UPPER WIND AT FREETOWN

By W. H. HOGG, M.Sc.

Pilot-balloon records from Freetown (8°30′N., 13°14′W.) giving the wind direction and speed at 0600, 1100 and 1600 zone time for intervals of a thousand feet are available for the period July 1944–June 1946. Ascents have now ceased and the two years' observations have been summarised to give some indication of the diurnal variation of wind in the lowest few thousand feet.

The use of mean values from pilot-balloon data has been criticised, as the results are usually biased in favour of clear weather with little cloud and light wind. Their use in the present investigation can, however, be justified on two grounds; first, that the bias is less marked near the ground than at a height of several thousand feet, and secondly, that any bias will be in favour of days with marked land and sea breezes, which are the main causes of the diurnal variation.

The data were summarised by computing monthly vectors for 0600, 1100 and 1600. In the computation, only those heights were included which were reached by each ascent during the day; for example, if the 0600 ascent reached

4,000 ft., the 1100 reached 3,000 ft. and the 1600 reached 5,000 ft., only the observations up to 3,000 ft. were included for this day. The monthly vectors were then combined to give vectors for the following seasons: dry season (December–April), first squall season (May–June), monsoon season (July–September) and second squall season (October–November). Table I contains these vectors for heights up to 4,000 ft.; they are measured clockwise in degrees from north and in knots. The vectorial differences from 0600 to 1100, 1100 to 1600, and 1600 to 0600 are shown diagrammatically in Fig. 1.

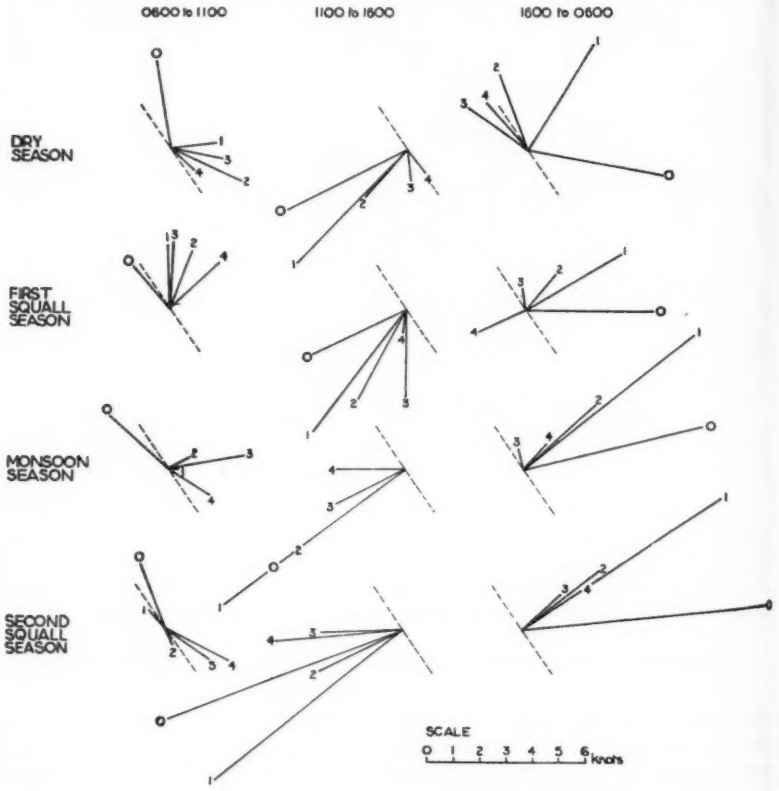


FIG. 1—MEAN VECTORIAL DIFFERENCES OF SURFACE AND UPPER WIND BETWEEN SUCCESSIVE OBSERVATIONS AT FREETOWN
Heights are given in thousands of feet at the end of each vector.
The broken lines show the general run of the coast.

The apparent diurnal variation of wind in the lowest few thousand feet, shown in Table I and Fig. 1, is presumably due to two main causes, *viz.* a land- and sea-breeze effect and " chance " variations which have not been smoothed out. The land- and sea-breeze effect can be defined as the variation which is due to relative changes of temperature and pressure over sea and land. The " effect " does not necessarily lead to an alternation of land and sea breezes; it may, for example, cause a weakening of a land wind during the day, or a sea wind at

night. As the effect of chance variations is probably small near the surface, where there are most observations, the vectors can be used to determine the approximate direction of the land- and sea-breeze effects.

A sketch of the coast near Freetown is given in Fig. 2 which suggests that the sea-breeze effect will be from north or north-west if it is determined by the

TABLE I—VECTOR WINDS AT FREETOWN

Height	0600		1100		1600		No. of observations	0600		1100		1600		No. of observations
ft.	° true	kt.	° true	kt.	° true	kt.		° true	kt.	° true	kt.	° true	kt.	
	Dry season							Monsoon season						
4,000	45	3·0	67	3·3	85	3·7	111	48	1·2	94	2·6	180	0·2	16
3,000	303	2·0	32	0·9	130	0·8	166	234	2·2	129	1·3	217	2·7	22
2,000	287	4·7	276	1·8	246	3·7	200	232	5·2	230	4·2	231	9·1	38
1,000	285	3·9	300	2·4	244	6·9	221	236	4·1	233	3·9	233	12·4	51
0	205	1·7	325	2·1	264	5·7	221	167	1·7	273	1·7	242	7·3	52
	First squall season							Second squall season						
4,000	111	2·3	77	4·0	90	3·8	15	84	6·3	93	8·8	103	4·1	41
3,000	180	0·7	3	1·8	180	1·5	21	84	2·7	103	4·5	128	1·7	53
2,000	232	2·2	305	1·2	226	3·9	37	74	0·7	108	0·9	229	2·9	59
1,000	228	2·9	283	2·3	235	6·9	46	108	0·9	45	0·6	231	8·5	64
0	171	1·2	294	1·2	255	4·8	46	107	3·9	65	3·1	251	6·5	64

*The ascents were made at Falconbridge Point 8°30′N., 13°14′W.

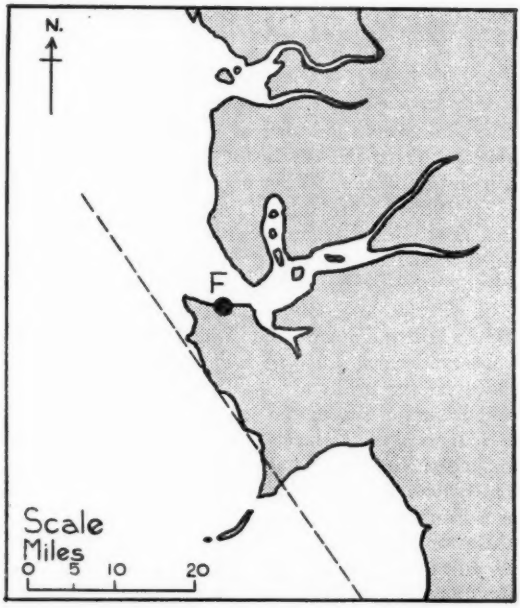


FIG. 2—POSITION OF FREETOWN IN RELATION TO THE RUN OF THE COAST

The broken line shows the run of the coast.

position of Freetown on the Sierra Leone peninsula, and from west or south-west if it is determined by the general run of the coast in this region.

From the data available, the best estimates of the direction of sea-breeze effect are given by the 1600 minus 0600 vectors, which can be obtained from Fig. 1 by reversing the 0600 minus 1600 vectors. In the dry season the surface sea-breeze effect is from north of west, in the first squall season it is from west, and in the other seasons from south of west. The direction of the sea-breeze effect at Freetown thus seems to be determined by general rather than local causes; this has also been found to be true for Scottish stations[1]*. The land- and sea-breeze effect can therefore be summarised by taking components normal to the general run of the coast in this part of west Africa. The components along the direction 235–55° are given in Table II, where positive values refer to winds blowing from sea to land.

TABLE II—COMPONENTS NORMAL TO THE COAST

Height	0600		1100		1600		0600		1100		1600	
ft.	*knots*											
	Dry season						Monsoon season					
4,000	−3·0	*−0·2*	−3·2	*0·0*	−3·2	*0·2*	−1·2	*−0·8*	−2·0	*2·1*	0·1	*−1·3*
3,000	0·7	*−1·5*	−0·8	*0·6*	−0·2	*0·9*	2·2	*−2·6*	−0·4	*3·0*	2·6	*−0·4*
2,000	2·9	*−1·5*	1·4	*2·2*	3·6	*−0·7*	5·2	*−1·0*	4·2	*4·9*	9·1	*−3·1*
1,000	2·5	*−1·5*	1·0	*5·8*	6·8	*−4·3*	4·1	*−0·2*	3·9	*8·5*	12·4	*−8·1*
0	1·5	*−1·5*	0·0	*5·0*	5·0	*−3·5*	0·6	*0·7*	1·3	*5·9*	7·2	*−6·4*
	First squall season						Second squall season					
4,000	−1·3	*−2·4*	−3·7	*0·6*	−3·1	*1·8*	−5·5	*−1·4*	−6·9	*4·2*	−2·7	*−2·1*
3,000	0·4	*−1·5*	−1·1	*2·0*	0·9	*−0·5*	−2·4	*−0·6*	−3·0	*2·5*	−0·5	*−1·9*
2,000	2·2	*−1·8*	0·4	*3·5*	3·9	*−1·7*	−0·7	*0·2*	−0·5	*3·4*	2·9	*−3·1*
1,000	2·9	*−1·4*	1·5	*5·4*	6·9	*−4·0*	−0·6	*0·0*	−0·6	*9·1*	8·5	*−9·1*
0	0·5	*0·1*	0·6	*3·9*	4·5	*−4·0*	−2·4	*−0·6*	−3·0	*9·3*	6·3	*−8·7*

*The changes from one observation to the next are shown in italics.

It is seen that in all seasons a land breeze is added to the 0600 wind between 0600 and 1100, except perhaps in the lowest few hundred feet in the first squall season and the monsoon season. This does not mean that the start of the sea-breeze effect is delayed until after 1100, but only that the total change between 0600 and 1100 adds a vector from land to sea. From 1100 to 1600 a sea breeze is added to the 1100 wind at all heights. Between 1600 and 0600 a land breeze is added to the 1600 wind; in the dry season and the first squall season this may be reversed at 3,000 or 4,000 ft.

During most of the year the mean wind in the lowest 2,000 or 3,000 ft. is from the sea at each observation; at 4,000 ft. it blows from the land. In the second squall season, however, the mean wind is from the land at all heights during the forenoon, and from the sea in the lowest 2,000 ft. during the afternoon.

The vectorial changes of the surface wind at Freetown are given in an earlier paper[2]. For comparison with Table I and Fig. 1 the values have been combined seasonally, and are given in Table III. The middle values for each season are the vector changes from 0600 to 1300.

The 0600 values for the 1942–44 and the 1944–46 series are very similar in the dry season and second squall season, and suggest that the data given for these seasons are more reliable than for the others. Assuming that in these seasons the surface data for the two periods are comparable, the vector changes from 1100 to 1300 and from 1300 to 1600 may give some indication of the time at which the sea-breeze effect is complete. In the dry season, the 1100–1300 change is 264° 3·0 kt. and the 1300–1600 change 227° 2·2 kt.; in the second

*The index numbers refer to the list of references on p. 137.

TABLE III—SEASONAL VECTORS FOR SURFACE WIND AT FREETOWN, 1942–44

The vector changes are shown in italics

0600				1300		0600				1300	
true	kt.	true	kt.	true	kt.	true	kt.	true	kt.	true	kt.
		Dry season						Monsoon season			
215	1·7	*306*	*3·8*	283	4·2	203	1·7	*257*	*4·3*	243	5·5
		First squall season						Second squall season			
147	1·8	*290*	*6·7*	278	5·4	107	3·6	*275*	*6·7*	262	3·3

squall season the values are 254° 6·3 kt. and 240° 3·3 kt. As the first changes occur within 2 hr. and the second in 3 hr., it seems that either the sea-breeze effect is producing more rapid changes before 1300 than after it, or else the effect ceases fairly soon after 1300. More frequent observations would be necessary to determine which of these alternatives is correct. The data for the other seasons, although probably less reliable, lead to similar conclusions.

REFERENCES

1. GOLDIE, A. H. R.; Wind records from Bell Rock Lighthouse. *Geophys. Mem., London*, **7**, No. 63, 1935.
2. HOGG, W. H.; The diurnal variation of surface wind at Bathurst, Freetown and Lagos. *Quart. J. R. met. Soc., London*, **72**, 1946, p. 335.

PREPARATION OF LINEAR-FUNCTION TABLES ON A HOLLERITH TABULATING MACHINE

By D. DEWAR, B.Sc.

General principles.—During a lecture on mechanical computing methods at University College, London, the lecturer, Dr. Hartley, described how tables of a linear function could be produced on a Hollerith printer-tabulator.

The method is very simple. For a table such as the conversion of metres to feet successive multiples of 3·2808 are required together with the appropriate multiple. About 50 Hollerith cards are punched diagonally as shown in Fig. 1 (*i.e.* 1 in column 1, 2 in column 2, etc.) By suitable plug-board connexions a number punched in any card column can be printed in any space on a print bank. Insertion of decimals and editing have to be done afterwards. Connexions are made so that a 3 from column 3 is printed near the left-hand side of the sheet followed after a gap by a 2 from column 2, an 8 from column 8, an 0 from column 10 and another 8 from column 18. When the machine is set for progressive totalling it prints the accumulated total after the passage of each card and by connecting a device known as the card count it also prints the total of the number of cards that have passed through the machine. This card count is arranged to print to the left of the totals. As the pack of cards goes through the machine conversion values are printed as shown below:—

1	3	2808
2	6	5616
3	9	8424
4	13	1232
..	..	..
50	164	040

The pack is then run through the machine again to give values from 51 to 100 and the operation repeated until enough values have been obtained.

FIG. 1—HOLLERITH CARD PUNCHED DIAGONALLY

For a single table such as this the required factor could, of course, have been punched successively on 50 cards; the object of the diagonal punching is to produce a pack of cards suitable for compiling any normal tables.

Application to upper air mean temperature tables.—When a start was made with the computation of monthly mean values of upper air temperatures from Hollerith cards it was soon found that though the totals of the daily values on the cards could be rapidly obtained on the tabulator a lot of time was being spent in working out means. The addition of 200 to the actual temperatures to eliminate minus values gave four-figure totals and incomplete observations gave varying divisors. It was evident that a lot of repetitive arithmetic would eventually be saved by producing suitable tables. The use of a tabulator to produce these tables made it practicable to do so. Owing to the large range of values and the varying number of observations 40,000 totals had to be given to cover the ranges 100° to −100°F. and 31 to 11 observations. It is doubtful if the production of such tables by clerical labour would have been worth while. A specimen of the tables is shown in Fig. 2. They were printed following the

Number of observations

Mean temperature °F.	31	30	29	28	27	26
+ 0·0	6200	6000	5800	5600	5400	5200
0·1	6203	6003	5802	5602	5402	5202
0 2	6206	6006	5805	5605	5405	5205
0 3	6209	6009	5808	5608	5408	5207
0 4	6212	6012	5811	5611	5410	5210
0 5	6215	6015	5814	5614	5413	5213
0 6	6218	6018	5817	5616	5416	5215
0 7	6221	6021	5820	5619	5418	5218
0 8	6224	6024	5823	5622	5421	5220
0 9	6227	6027	5826	5625	5424	5223
1 0	6231	6030	5829	5628	5427	5226
1 1	6234	6033	5831	5630	5429	5228
1 2	6237	6036	5834	5633	5432	5231
1 3	6240	6039	5837	5636	5435	5233
1 4	6243	6042	5840	5639	5437	5236
1 5	6246	6045	5843	5642	5440	5239
1 6	6249	6048	5846	5644	5443	5241
1 7	6252	6051	5849	5647	5445	5244
1 8	6255	6054	5852	5650	5448	5246
1 9	6258	6057	5855	5653	5451	5249
2 0	6262	6060	5858	5656	5454	5252
2 1	6265	6063	5860	5658	5456	5254
2 2	6268	6066	5863	5661	5459	5257
2 3	6271	6069	5866	5664	5462	5259
2 4	6274	6072	5869	5667	5464	5262
2 5	6277	6075	5872	5670	5467	5265
2 6	6280	6078	5875	5672	5470	5267
2 7	6283	6081	5878	5675	5472	5270
2 8	6286	6084	5881	5678	5475	5272
2 9	6289	6087	5884	5681	5478	5275

FIG. 2—TABLE FOR OBTAINING MEAN TEMPERATURES FROM HOLLERITH TABULATOR TOTALS

general principles described in the above paragraph. To get the first line of the table in Fig. 2 a suitably punched card was put through first. It will be noticed that the difference for some columns is not entirely constant; for the column headed 29, for instance, it is occasionally 0002. This is because an extra figure was used in the adding part of the machine to get greater accuracy but was suppressed at the printing stage. The figures in the body of the table are the totals as given by the tabulator and incorporate the 200 added to each individual

value. To find the mean for a given total the table is entered under the heading giving the appropriate number of observations, and after locating the total in this column the mean temperature is the value in the left-hand column in line with this total.

The tabulator can add and print each line of figures in about 0·6 sec. so the actual printing took about 40 min. Setting up and adjusting the lay-out made it a day's work, however.

The sheets obtained from the tabulator were then edited and sent to the Air Ministry Photographic and Reproductions Branch for copies to be made, each sheet being reduced to foolscap size. The tables have already been found a great convenience and should soon repay the time spent on their production.

CONVERSION OF PERCENTAGE FREQUENCIES OF FOG AND OF SLEET OR SNOW TO DAYS PER MONTH, AT SEA

By E. V. NEWNHAM, B.Sc.

The monthly meteorological charts for the oceans prepared by the Marine Branch of the Meteorological Office include charts on which lines of equal percentage frequency of gales, fog, sleet or snow, etc., are shown. For some purposes it is preferable to know the number of days per month on which the phenomenon occurs. The observing routine on ships keeping meteorological logs on which the charts are based—observations at 4 a.m., 8 a.m., noon, 4 p.m., 8 p.m. and midnight—does not make it possible to find out exactly what is required, but it is possible to relate percentage frequency to the average number of days per month on which the phenomenon occurs at one or more of these six hours of observation. In the case of fog this number is probably only very slightly less than the number of days with some fog, irrespective of the time of its occurrence, since it is probably exceptional for fog to occur without there being some at one or more of these six hours. In the case of sleet or snow the difference is probably rather larger, for on days with only a few brief snow flurries, snow may fairly often be absent at all the six hours of observation.

For a 30-day month the number of observations is 6×30 and the average number of observations of the phenomenon will be $6 \times 30 \times P$, where P is the percentage frequency. The average number of days per month on which the phenomenon occurs at one or more of the six hours of observation is clearly $180\ P/n$, where n is the average number of hours of observation out of the six on which the phenomenon is observed, on days when it is observed at, at least one of the hours.

Areas over which P for a given month was as nearly as possible constant were chosen, and n was obtained for each area by examination of the logs of all observing ships during the period when they were within that area in the appropriate month. The mean value of P was estimated from the lines of equal percentage frequency.

For fog, five areas which included the North Sea and various parts of the North Atlantic north of lat. 40°N. were selected, the month chosen being May, as this gave a sufficiently large number of fog days. The following figures were obtained:—

TABLE I

Percentage frequency	2½	5	11½	25	35
No. of fog days	50	50	38	31	65
n	2·26	2·24	2·34	2·74	3·66

For sleet or snow three suitable areas were found between 30°W. and 40°W., and 40°N. to 55°N. The period covered was December 20 – March 15. The following figures were obtained:—

TABLE II

Percentage frequency	5	9	13
No. of days with sleet or snow	32	38	54
n	2·7	2·6	2·3

Since it is unlikely that *n* really decreases as the percentage frequency increases, it is reasonable to attribute the above differences to lack of sufficient numbers of observations to give accurate means, and to assume that *n* is 2·50, the ratio of the total number of observations of sleet or snow (310) to the total number of days of snow (124). The figures for *n* in Table I are also subject to error, and an approximation to their true values was obtained by plotting *n* and the percentage frequency and drawing a smooth curve passing near to the points so obtained. In this way required values of *n* were obtained and the figures shown in Table III were calculated, to which have been added those for gales, which last appear on the monthly meteorological charts previously referred to.

TABLE III

Percentage frequency	1	5	10	15	20
Days per month of fog	1	4	8	11	14
Days per month of sleet or snow*	1	3–4	7	11	14–15
Days per month of gale	1	3–4	6–7	9	12

*The isopleths on the marine charts headed *Snow* (s) refer to occasions when the letter (s) had been logged, irrespective of whether it occurred in combination with r, signifying sleet, or without r, signifying snow. These isopleths therefore show frequency of snow or sleet taken together, and not snow.

TEMPERATURE AND HUMIDITY LAPSE RATES NEAR THE OCEAN SURFACE

By A. H. GORDON, M.S.

During the course of a voyage undertaken by Mr. O. M. Ashford of the Instruments Branch of the Meteorological Office and the author to station JIG in the ocean weather ship *Weather Recorder* in July 1948 opportunity was taken to make trial observations of the temperature and humidity lapse rates near the surface of the ocean by means of a balanced-bridge psychrometer. The observations were made by the following methods :—

(*a*) The psychrometer was hoisted up the side of the ship to the mast by a rope and pulley arrangement.

(*b*) The psychrometer was lifted by a tethered balloon controlled from a rubber dinghy a short distance away from the ship.

Method (*b*) could only be undertaken on occasions when the wind was force 3 or less and the state of the sea calm or slight.

These experimental trials proved quite successful so that arrangements were made by the Marine Branch of the Meteorological Office for their continuation aboard the ocean weather ships when weather conditions permitted. Some results of observations made during the course of a voyage to station JIG in July 1949 are now available and are shown in Figs. 1 and 2.

These three examples are representative of three distinct degrees of temperature lapse rate, superadiabatic, isothermal and inversion, respectively. In Fig. 1, method (*a*), the temperature decreases a degree Fahrenheit in 50 ft. approx. and the lapse rate is therefore superadiabatic within this layer. On this occasion station JIG was situated on the western edge of a ridge of high pressure. The wind had backed to WSW. force 3. The air mass was polar maritime and had travelled around the eastern side of the ridge from more northerly latitudes. This air was consequently cooler than the sea surface and comparatively dry.

In Fig. 1, method (*b*), the station was in a warm sector and the pressure gradient was weak. The wind was S. force 3. The air was returning polar maritime and was almost at the same temperature as the sea surface. The lapse rate was isothermal. The air in this case was undergoing a transitional period of modification as it changed from polar maritime to tropical maritime class.

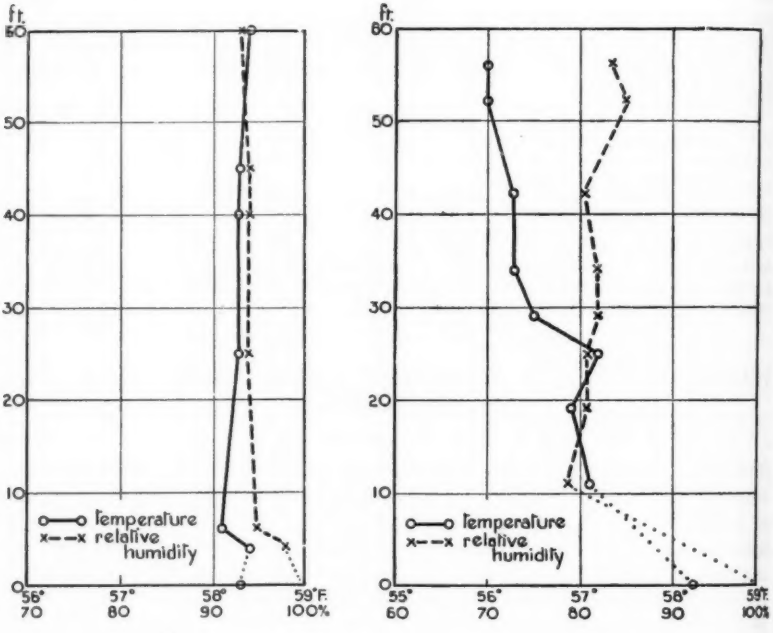
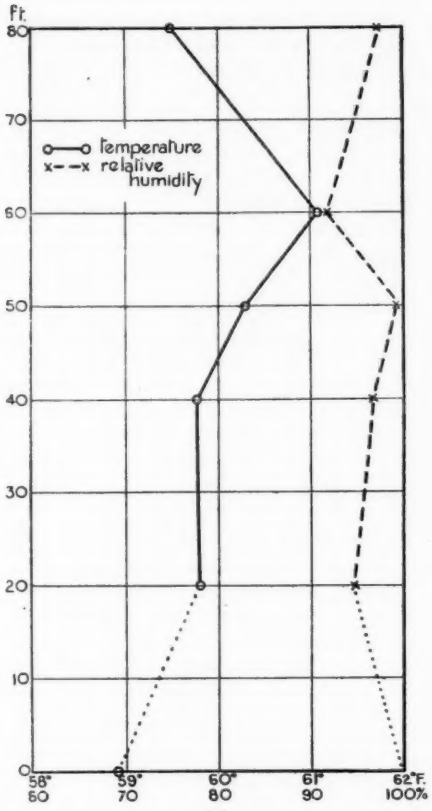


FIG. 1—LAPSE RATE OF TEMPERATURE AND HUMIDITY AT STATION JIG

In Fig. 2 the station was situated in tropical maritime air behind a warm occlusion. This air also appeared to be originally of polar maritime class. However, in this case the modification process had been carried much further so that the air could be termed tropical maritime when it covered station JIG. The air was warmer than the sea surface, and an inversion extended to 60 ft. above the sea surface above which the temperature commenced to decrease. The air was also much damper than in either of the other two cases.



(b)

1700 G.M.T. July 24, 1949

FIG. 2—LAPSE RATES OF TEMPERATURE AND HUMIDITY AT STATION JIG

It appears therefore that the temperature and humidity lapse rates near the ocean surface may provide a good criterion for the identification and classification of the existing air mass.

RADAR WEATHER ECHOES

By R. F. JONES, B.A.

Part II

The warm front by radar.—The generation of rain at the warm front of a depression has long been recognised as a much more gradual and wide-spread effect than the processes which take place at the cold front, and the radar evidence in no way contradicts this idea.

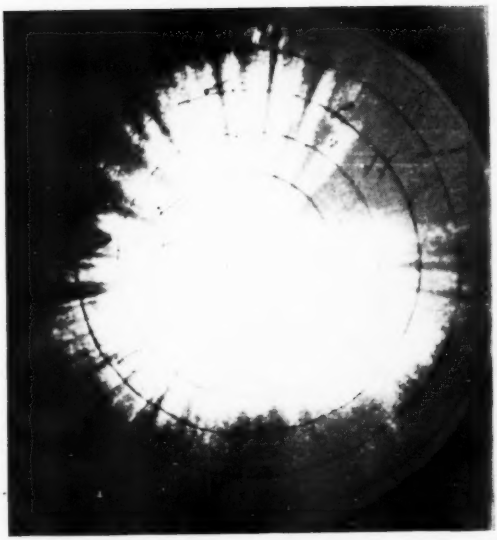
The typical P.P.I. picture (see photograph (*a*) of the series of photographs between pp. 144) of the precipitation associated with an active warm front is one of wide-spread and diffuse echoes with no clearly marked boundaries, and, although the intensity of the echo may be high, there are no indications of rapid variations in this intensity. The cores of high intensity, which are characteristic of the cold-front echo and which have been interpreted as evidence

of localised strong vertical currents, are generally completely absent from the warm-front echo and the whole picture suggests a much more uniform precipitation rate over a much larger area.

The first indication of the approach of a warm front on the P.P.I. is the appearance on the display tube of weak and diffuse patches of echo at fairly short ranges (see photograph (*b*)) which are associated with the first detectable precipitation, not necessarily reaching the ground, from the altostratus sheet of the front. As the front continues its approach these weak and diffuse patches move closer to and past the station, while the heavier precipitation closer to the front begins to show up in the form of an echo which gradually increases in size and intensity (see photograph (*c*)). Further progress by the front brings the heavier precipitation across the station until the P.P.I. picture shows one large mass of echo more or less symmetrically distributed around the station and fading gradually with range (photograph (*a*)). The range at which the echo fades varies, of course, for each warm front, principally on account of the various rainfall intensities, but for an active warm front, with our equipment, the range is of the order of 30–50 miles. Such a picture may persist for some time depending on the width of the rain area associated with the front and the speed of movement of the front, but ultimately one notices a decrease in the range at which the echo fades in the direction of the front and the appearance of a more or less straight edge to the echo in this direction. This edge is not usually very clearly defined and marks the surface position of the warm front (photograph (*d*)). Behind this edge in the warm sector of the depression a few diffuse patches of echo sometimes persist, particularly in the neighbourhood of high ground where orographic precipitation is taking place, but even with very damp air in the warm sector and outbreaks of drizzle there is very little echo to be seen. It is noteworthy that the decrease in drop size from raindrops to drizzle drops is sufficient, with this equipment, to lead to a disappearance of the weather echo, at least beyond 10 miles, a fact which is not surprising when it is remembered that the received echo power is related to the sixth power of the drop diameters. Forced ascent of the warm air over high ground, however, leads to an increase in size of the waterdrops, and the occasional appearance of an echo in such areas. Therefore with a warm front as distinct from a cold front, the clearance of the weather echo does not necessarily indicate a break in the cloud or improvement in surface weather conditions but frequently only a decrease in drop size of the precipitation—a factor which actually leads frequently to a deterioration in surface conditions.

In the vertical cross-section the warm-front echoes are also seen to have a characteristic structure different from the typical cold front. The most outstanding characteristic is the appearance on almost every occasion of a bright band in the vicinity of the freezing level, while the remainder of the echo has a diffuse appearance and is free from marked columns or clear-cut edges (see photograph (*e*)). As mentioned earlier the bright band occurs in conditions of low vertical-current speeds and has been explained as coming from melting ice crystals or snow-flakes[1]* An alternative explanation has been proposed by Byers and Coons[2]. With either of these explanations it can be said that the echo above the bright band is almost certainly received from large ice crystals or snow-flakes while with equal certainty the echo from beneath the bright band comes from raindrops. In some of the weaker warm fronts only

*The index numbers refer to the list of references on p. 145.

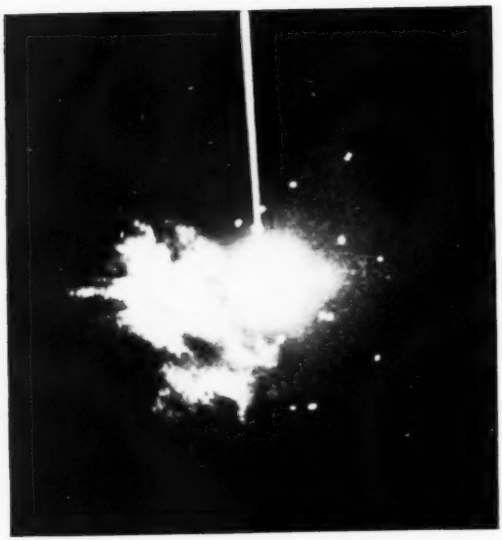


(*a*)

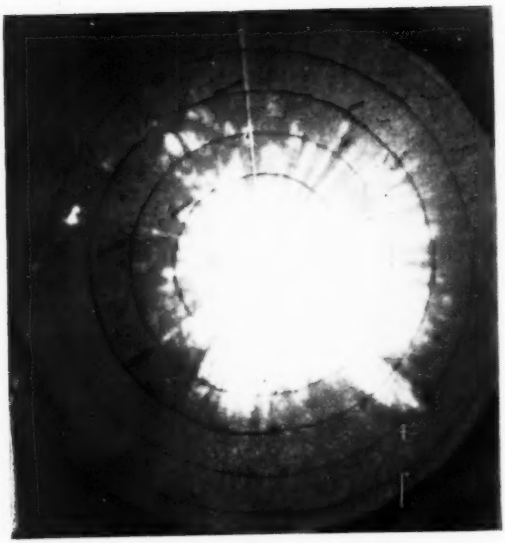
(*b*)

WARM FRONT BY RADAR

(see p. 143



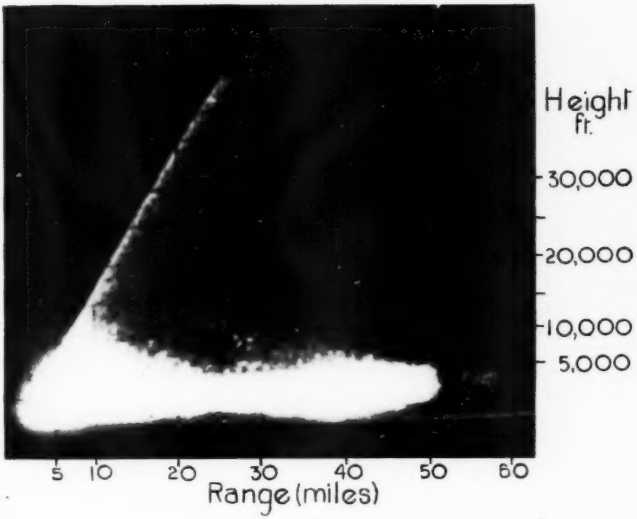
(*c*)



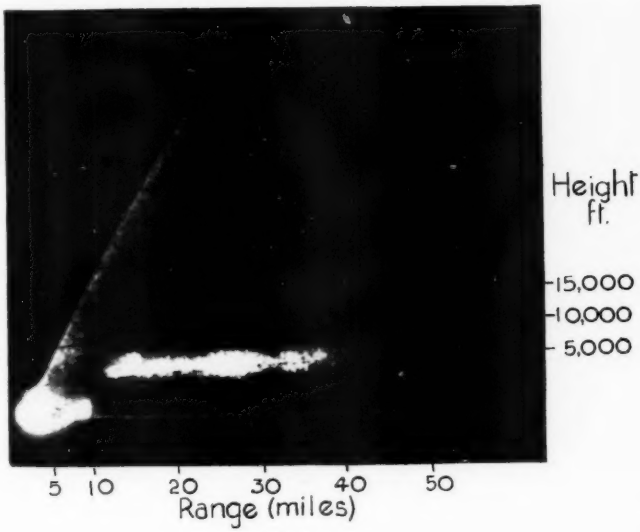
(*d*)

WARM FRONT BY RADAR

(see p. 143)



(*e*)



(*f*)

WARM FRONT BY RADAR

(see p. 143)

Reproduced by permission of J. F. Steljes

CLEAR LANE CUT IN ALTOCUMULUS BY AN AIRCRAFT

(see p. 153

Reproduced by permission of J. D. Hastings

SUN PILLAR AT WEST RAYNHAM, 1630 G.M.T., JANUARY 21, 1950

(see p. 153

the bright-band echo is visible (photograph (*f*)). The diffuse nature of the echo above the bright band and lack of well marked edges has been interpreted as evidence of weak but wide-spread upward currents with little or no turbulence[3].

Once more it can be stated that the radar evidence is in agreement with the generally accepted idea of the warm-front precipitation as being due to the slow and uniform ascent of the air over a wide area.

Further details of the photographic illustrations and their interpretation follow below:—

Photograph (*a*).—This photograph was taken at 1030 G.M.T. on April 23, 1947. The circular black markers are at 10-mile intervals from the radar set which is situated, of course, at the centre of the picture. The first easily discerned marker is at a range of 20 miles. The single radial black line is along magnetic north. The gaps in the echo along radial lines from the station are not due to variations in the precipitation rate but to screening of the radio energy close to the transmitter by trees. Note the gradual fading of the echo with range.

Photograph (*b*).—This was taken at 0923 G.M.T. on April 23, 1947, *i.e.* the same warm front as in photograph (*a*). The echoes inside the first 10-mile marker are from permanent echoes due to high ground, but the echoes to the west are the first signs of the precipitation from the approaching warm front.

Photograph (*c*).—This photograph was taken at 1623 G.M.T. on December 6, 1948. The bright radial line is along magnetic north. Range markers are not visible on the photograph but the furthest bright echo to the west is from about 45 miles (the echo extends weakly to about 50 miles). There is a weak diffuse echo over the station which partly hides the permanent echoes, and comes from the initial light precipitation of the front. The bright spots of echo are from aircraft.

Photograph (*d*).—This is again associated with the same frontal precipitation as in photographs (*a*) and (*b*) and was taken at 1324 G.M.T. Note how the range to which the echo extends has decreased to the west and north-west and the appearance of an ill-defined edge lying approximately north-east to south-west about 20 miles from the station.

Photograph (*e*).—This H.R.T. photograph was taken at 1248 G.M.T. on March 4, 1949, on a bearing of 290° true. Note the bright band of echo centred at about 2,500 ft. extending to 50 miles, and the diffuse nature of the echo above this band. The freezing level was 3,500 ft. at Larkhill at 0900 G.M.T. falling eastwards to 2,000 ft. at Downham Market.

Photograph (*f*).—This H.R.T. photograph was taken at 1202 G.M.T. on January 15, 1949, on a bearing of 357° true. It is associated with a rather weak and slow-moving warm front and only the bright band in the vicinity of the freezing level is visible.

REFERENCES

1. RYDE, J. W.; The attenuation and radar echoes produced at centimetre wavelengths by various meteorological phenomena. Physical and Royal Meteorological Societies' report on " Meteorological factors in radio-wave propagation". London, 1946, p. 169.
2. BYERS, H. R., and COONS, D.; The ' bright line ' in radar cloud echoes and its probable explanation. *J. Met., Lancaster Pa.*, **4**, 1947, p. 75.
3. JONES, R. F.; The heights and temperatures at the tops of radar echoes associated with various cloud systems. *Met. Res. Pap., London*, No. 458, 1949.

METEOROLOGICAL OFFICE DISCUSSION

The Discussion, held at the Imperial College on March 13, 1950, and opened by Mr. J. S. Sawyer, dealt with the formation and behaviour of secondary depressions on warm fronts, cold fronts and occlusions.

Mr. Sawyer referred to a discussion held two years ago at which Dr. R. C. Sutcliffe advocated the use of charts of the thickness of the 1000–500-mb. layer as a tool in forecasting practice[1]*. A series of investigations into the formation and behaviour of secondary depressions has since been carried out at the Central Forecasting Office, Dunstable, and an attempt has been made to relate their occurrence to features of the thickness pattern. The results of the study of secondary depressions on warm fronts and occlusions has already been summarised in the *Meteorological Magazine*[2], but the investigation of cold-front waves has not yet been published.

The investigations have been primarily empirical; occasions of the formation of secondary depressions have been noted and the corresponding thickness pattern examined on a thickness chart of the 1000–500-mb. layer. It was found possible to identify thickness patterns characteristic of the formation of secondaries on warm fronts and warm occlusions, and also on cold occlusions. These have already been described[2]. It had not been possible to establish any particular thickness pattern as characteristic of cold-front waves, although many formed between 200 and 600 miles east of a trough line in the thickness pattern. Dr. Sutcliffe[3] has shown theoretically how cyclonic and anticyclonic development can be related to the thermal wind field and thickness pattern. The results of the investigations of secondary depressions were consistent with these ideas. Warm-front and warm-occlusion secondaries were found to form to the right of a confluence in the thermal wind field, and the cold-occlusion secondaries were found to the left of a diffluence. Both of these areas should be cyclogenetic according to Sutcliffe's theory. Moreover, charts had been drawn presenting the numerical evaluation of the expression derived by Sutcliffe for the cyclonic development, *viz.*—

$$-\left\{V'\frac{\partial\zeta'}{\partial s}+2V'\frac{\partial\zeta_0}{\partial s}\right\}$$

in which V' is the thermal wind speed,

ζ' is the vorticity of the thermal wind,

ζ_0 is the vorticity of the surface geostrophic wind field, and

$\partial/\partial s$ denotes differentiation in the direction of a thickness line.

Cyclonic maxima of this expression had shown a close association with secondary development.

An examination of all the cold-front waves which formed over Europe and the eastern Atlantic during the course of a year has revealed the following facts:—

(*a*) none formed on cold fronts less than 1,200 miles long;

(*b*) many of the waves appeared to be the result of the distortion of the front either by hills or by neighbouring pressure systems;

(*c*) of the remainder, 26 out of 31 formed in areas classified as cyclogenetic by inspection on the basis of Sutcliffe's theory.

*The index numbers refer to the list of references on p. 149.

The polar-front theory of depressions treats the wave depressions as unstable oscillations of the front, and Solberg[4] has shown mathematically that unstable disturbances of the right type and dimensions should exist. If this point of view is correct we should not expect to predict the exact time or place for the formation of a wave, and the best that can be expected is a criterion which will indicate whether a front is unstable or not. The mathematical treatments of waves on fronts show that there is a lower limit to the wave-length for which waves are unstable, and the fact that there seems to be a sharp lower limit of 1,200 miles on the length of a front capable of forming waves might be regarded as conforming with the instability theory. However, the fact that some other cause for wave formation appears to exist in respect of nearly all waves seems to be against any theory depending on instability alone. The apparent cause may be either kinematic, as when the front is distorted by neighbouring pressure systems or by hills, or it may be dynamic, as when there is a "cyclonic-development" area associated with a maximum of Sutcliffe's expression.

Perhaps we can resolve these points of view by regarding the front as unstable, but the growth of individual waves so slow that they cannot start as infinitesimal perturbations.

A finite disturbance has to be set up if the wave is to become of significant amplitude before it runs out of the frontal belt.

The work on cold-front waves seems to suggest or confirm the following rules for forecasting:—

(1) If a cold front extends over a length of 1,200 miles or more and is associated with a 25-kt. thermal wind (1000–500 mb.) over this length, a new wave should be expected on it.

(2) New waves should not be inserted on shorter fronts, or on fronts not fulfilling condition (1).

(3) On fronts satisfying condition (1) the wave may be expected to develop:—

(*a*) where the front is subject to orographic distortion;

(*b*) where a bulge in the front can be produced by a flow round adjacent pressure systems;

(*c*) where the thermal vorticity term is maximum (often 200 to 600 miles east of a thermal trough line).

(4) Both thermal wind and the direction of the warm-sector isobars are a good guide to the direction of motion of a newly formed wave.

(5) The speed of a newly formed wave is not closely related to the thermal wind speed—probably four fifths of the geostrophic wind speed in the warm sector is a reasonable estimate.

The Director said that the importance of secondary developments was emphasised by the fact that, in an analysis of errors in forecast charts prepared at the Central Forecasting Office, one third of all significant errors could be attributed to such new formations.

Dr. Farquharson said the characteristic thickness patterns of secondary depressions were often referred to in forecast discussions at the Central Forecasting Office. Their application to forecasting was limited by the need to anticipate

the development of the thickness pattern itself, and by the difficulty of fixing precisely the time of formation and track of the secondary, both of which have a considerable influence on the weather forecast. The vorticity computations referred to by Mr. Sawyer could not be applied to forecast charts as such charts were not sufficiently accurate for the purpose. Dr. Farquharson also asked whether the jet stream was essential to the formation of occlusion secondaries or merely incidental—Mr. Sawyer thought it was an important factor.

Mr. Harley (London Airport) quoted developments in the 24 hours before the meeting as a good example of the value of thickness patterns in forecasting.

Mr. Zobel said that he had obtained only very limited success in the use of thickness patterns in forecasting. He quoted February 8 and 21, 1950, as occasions when developments were contrary to indications of the thickness pattern.

Mr. Lamb inquired if there was any method of applying the results in regions such as the Southern Oceans for which no upper air observations were available. He remarked that the formation of waves through distortion of fronts by influence of neighbouring pressure systems was a well tried forecast tool. He also asked if small stable waves were not found on fronts less than 1,200 miles long. Mr. Sawyer, in reply, said that waves of length less than 200–300 miles had been excluded from the analysis.

Mr. Scorer (Imperial College) remarked that theoretical studies of unstable atmospheric waves, such as those due to Dr. Eady, might provide much knowledge as to how the energy of translation is transformed into energy of rotation, and also regarding potential energy changes in depressions.

Mr. Lumb referred to the formation of secondary depressions in the lee of the Alps. In these, the cold front crossed the mountains and moved ahead as an upper cold front. The subsequent development of the lee depression took place behind the front, and was more closely associated with the distortion of the wind and thermal fields by the mountains than with the front itself.

Miss Carruthers remarked that statistically the relation between secondaries and the thickness pattern appeared to be highly significant.

Mr. Illsley remarked that the suggested application of thickness patterns to forecasting was more difficult at local meteorological offices with limited resources than it was at the central office. He also suggested that the ideas be tested on charts drawn in some service where the thickness pattern was not being used as a forecasting tool in this way.

Mr. Galloway referred to recent work in America which suggested that a major contribution to surface pressure changes came from the sub-stratosphere. He thought a level above 500 mb. would be more significant than those used in the present investigations. He also referred to the gravitational effects of masses of air. In reply, Mr. Sawyer considered that great caution was necessary in attributing the cause of pressure changes to specific layers on account of density changes; convergence of air at one level was nearly always balanced by divergence in another and the changes in a vertical column were only a small residual.

Mr. Bannon pointed to the approximations in the derivation of the basic equations of Sutcliffe's theory. He thought its failures occurred when the omitted factors were significant.

Dr. Sutcliffe remarked that most of the omitted terms were zero if no development were taking place. He thought, therefore, that the derived expression was a legitimate criterion of development. In the past, theoretical meteorologists had been content to concentrate on the explanation of what the synoptic meteorologist observed. Now, however, there were signs that the theorists were moving ahead; his own work[3] and more recently that of Charney[6] had predicted features of the atmospheric flow not previously recognised by the empiricists. In 20 years' time progress in meteorology may be from the theoretical to the practical instead of the reverse.

Secondary depressions appear to be slow moving at first but subsequently move more quickly; they appear to need to attain a finite size before they break away; there is an analogy with eddies forming in the lee of an obstacle.

The application of vorticity methods needs much experience because third-order differentials are involved; it is desirable to extend charts over a wide area.

The Director, summing up, said that despite its limitations he considered the technique of the use of thickness patterns in the manner described was extremely important. It provided a means by which synoptic meteorology could escape from the bondage of empiricism.

REFERENCES

1. SUTCLIFFE, R. C.; The use of upper air thickness patterns in general forecasting. *Met. Mag., London*, **77**, 1948, p. 145.
2. SAWYER, J. S.; Formation of secondary depressions in relation to the thickness pattern. *Met. Mag., London*, **79**, 1950, p. 1.
3. SUTCLIFFE, R. C.; A contribution to the problem of development. *Quart. J. R. met. Soc., London*, **73**, 1947, p. 370.
4. BJERKNES, V., BJERKNES, J., SOLBERG, H. and BERGERON, T.; Physikalische Hydrodynamik. Berlin, 1933.
5. CHARNEY, J. G. and ELIASSEN, A.; A numerical method for predicting the perturbations of the middle latitude westerlies. *Tellus, Stockholm*, **1**, No. 2, 1949, p. 38.

METEOROLOGICAL RESEARCH COMMITTEE

The ninth meeting of the Physical Sub-Committee of the Meteorological Research Committee was held on February 16, 1950.

The Chairman's report to the Committee was discussed and the Sub-Committee also formulated recommendations for the revision of Part III of the Research Programme.

The view of the Sub-Committee on the desirability of including on the tephigram saturated adiabatics for liquid water at temperatures below 0°C. had been sought, and the Sub-Committee recommended in favour of doing this.

Papers considered included one dealing with the horizontal dimensions of cumulonimbus clouds by R. F. Jones[1], based upon radar observations and one dealing with the size of cloud particles by A. C. Best[2].

[1] *Met. Res. Pap., London*, No. 535. [2] *Met. Res. Pap., London*, No. 538.

OFFICIAL PUBLICATIONS

Manuals of Meteorological Practice

A number of manuals and handbooks are in course of compilation which describe in considerable detail the technical procedure and practice followed within the Meteorological Office. Among them are the " Manual of Meteorological Observing " and the " Manual of Meteorological Instruments ". The first

of the series to be completed is the " Manual of Meteorological Statistics " which has been written by Dr. C. E. P. Brooks and Miss N. Carruthers. This book has been sent for printing and it is hoped that copies will be available by the autumn of 1950. A short abstract of the Manual follows.

Manual of meteorological statistics

This Manual is in three parts. Part I deals with the nature of observations, the study of frequency distributions of different climatic elements, significance tests and the construction of normal values. Part II discusses the relations between two or more variables, correlation, smoothing, and the fitting of curves to observed data, and includes a chapter on vectors with special reference to winds. In Part III the authors deal with time-relations in meteorology. This includes the " persistence " of a phenomenon from one observation to the next, harmonic analysis and various methods of searching for hidden periodicities. The illustrations and examples are drawn almost entirely from meteorological sources.

The following publications have recently been issued:—

PROFESSIONAL NOTES

No. 99—Possible effects of heavy rain on aircraft. By J. S. Sawyer, M.A.

Heavy rain may produce downward air currents by frictional drag, or by cooling the air and making it denser than the surrounding air. An aircraft might also experience a downward thrust in rain on account of the weight of the rain or the impact of the drops. In this note the relative importance of these effects is examined.

It is concluded that the most important factor in producing downward air currents in rain is the cooling of the air by the evaporation of the drops. The effect of frictional drag of the drops is much smaller, except during exceptionally heavy rain. The direct effect of the impact or weight of the rain on the aircraft is negligible.

No. 100—Prediction diagram for radiation fog. By W. C. Swinbank, B.Sc.

Radiation fog is caused by the cooling of the surface air below the dew point. Cooling is aided by clear skies and by conditions of calm, when there is no tendency for eddy transfer of heat in the vertical. A high dew point requires the retention of the water vapour already present in the surface layer or an increase by diffusion downwards. These conditions require a small or negative decrease of vapour pressure with height, or " hydrolapse ". The occasions of wide-spread or local fog and of no fog, over south-east England in October and November 1936–41 were plotted against the square of the wind shear (measured as the difference between wind speed at the surface and the gradient wind) and the hydrolapse, and it was found possible to distinguish three regions—wide-spread fog, local fog and no fog. Prediction of fog by this diagram was improved by adding a supplementary diagram, introducing depression of dew point below dry bulb temperature. A similar diagram was constructed for Lincolnshire and Yorkshire. It was also found possible to relate the time of formation of fog, in hours after sunset, to the same factors.

No. 5—Aviation meteorology of the route Castel Benito—Cairo

This report describes the climate of the air route from Tripolitania to Lower Egypt from the point of view of aviation. The movement of depressions and fronts and the associated weather on the various sections of the route are described. Visibility, cloud, wind, rainfall, etc., are discussed individually for the different seasons of the year. A number of climatic tables are given.

Much of the air route lies over desert areas and fine weather predominates. Probably the most important interruptions to flying on the route are due to the occasional wide-spread sandstorms which occur chiefly in the winter and spring. Settled fine weather is experienced in summer. In winter, although fine weather predominates, there are periods of showery weather with local thunderstorms. These disturbed conditions are appreciably more frequent over the western part of the route than over the eastern section.

ROYAL METEOROLOGICAL SOCIETY

The meeting of the Society on February 22, 1950, Dr. R. C. Sutcliffe in the chair, was devoted to the subject of radar echoes from cloud and precipitation.

The meeting opened with a short film from the records of the Massachusetts Institute of Technology, presented by Dr. Wexler. The film was composed of photographs of the height-range indicator tube taken at intervals during a period of precipitation and speeded up to show the development and movement of the weather echoes. Mr. Hooper then read the following paper.

J. E. N. Hooper and A. A. Kippax—"The bright band—a phenomenon associated with radar echoes from falling rain".

Mr. Hooper showed that when frontal rain is viewed with a vertically-looking radar, using a wave-length of 3 cm., echoes are received which exhibit a characteristic layer of greater intensity near the freezing level. Observations made at Larkhill at the same time as the radio-sonde ascents enabled the height of this layer or " bright band " to be determined relative to the freezing level, and it was shown that the bright band lies on the average 330 ft. below the freezing level, with a probable error of 150 ft. The explanation of the bright band due to Ryde* leads one to expect that the ratio of bright-band intensity to the intensity of the echo from the rain beneath will be equal to the ratio of the terminal velocities of a raindrop to those of a snow-flake of equal mass. Observations of the terminal velocities of snow-flakes made by the authors and others were described, and it was shown that the ratios of the terminal velocities of raindrop and snow-flake so obtained were in the same range of values as the ratio of echo intensities from the bright band to those from the rain below.

Mr. R. F. Jones then opened the general discussion on radar echoes by describing some of the investigations which had been made at East Hill. Evidence had accumulated to support the belief that temperatures at the tops

*RYDE, J. W.; The attenuation and radar echoes produced at centimetre wavelengths by various meteorological phenomena. Physical and Royal Meteorological Societies' report on " Meteorological factors in radio-wave propagation ". London, 1946, p. 169.

of weather echoes are an indication of the relative strengths of the vertical currents within the echoes. Thus thunderstorm echoes usually extended to temperatures around −40°F. or below while the tops of echoes associated with the weak up currents of layer clouds and weak fronts did not reach to temperatures colder than 16°F. Two types of echo were indicated, the bright-band echo from layer and frontal cloud and the cumulonimbus echo which appeared as a strong column of echo without bright-band characteristics. This lead to a theory that the echoes from cumulonimbus clouds were from raindrops at all heights, and he suggested that growth to raindrop size in such clouds occurred by coalescence and condensation without the aid of an ice crystal.

A lively discussion followed in which Messrs. Mason, Wexler, Browne, Galloway, Ludlam and others took part. The mechanism of ice-crystal aggregation to form snow-flakes, the possibility of wet hail rather than water-drops as the explanation of the cumulonimbus echo and the question whether the bright band was not after all present, although at times in a very weak form, in cumulonimbus clouds were among the many points raised. Mr. E. Gold stressed the point that radar has provided a powerful new tool for the meteorologist.

Brief replies to the discussion were made by Messrs. Jones, Hooper and Kippax but time did not permit of detailed replies.

LETTER TO THE EDITOR

Relation between number of days with 0·4 in. or more of rain and total rainfall

You may like to have a few additional details about the relation between the number of days with 0·4 in. (10 mm.) or more and the total rainfall, discussed by Mr. Newnham in the *Meteorological Magazine* for January 1950. When this question first came up in 1941, the idea of comparing number of days with 0·4 in. or more with total rainfall rather than with number of days with 0·01 or 0·04 in. was arrived at by simple reasoning and checked by correlation, but I was agreeably surprised by the magnitude of the correlation coefficients. These were:—

	No. of stations	Winter	Spring	Summer	Autumn	Year
Western and northern Europe	19	+0·97	+0·92	+0·93	+0·98	..
British Isles	18	..	..	..	..	+0·984
Norway	34	..	..	..	..	+0·985
Southern South America	5	..	..	..	..	+0·998

The first and last of these groups included stations in a wide variety of climates. The regression equations for the annual values all approximated to the form:–

$$\text{Days with 0·4 in. or more} = R - c$$

where R is measured in inches, but the value of c varied from 6 in South America to 12 in the British Isles. It is evident from Mr. Newnham's Fig. 1 that this relation extends to months as well as seasons.

It may be of interest to add that in the British Isles:

$$\text{Days with 0·2 in. or more} = 1{\cdot}5R + 6$$

where R is in inches. For days with rainfall above 0·5 in. this type of relation no longer holds.

January 30, 1950 C. E. P. BROOKS

NOTES AND NEWS

Clear lane cut by aircraft in altocumulus

We are indebted to Mr. J. Paton for drawing attention to the photograph shown facing p. 145, and to the photographer and owner Mr. J. F. Steljes for permission to print it. The photograph shows a clear lane left in altocumulus cloud by the precipitation of ice crystals after the passage of an aircraft through the cloud*. The precipitation was presumably caused by artificial nucleation of the supercooled droplets. The photograph was taken at Edinburgh at 0945, March 30, 1944.

The south of Scotland on the morning in question was in a cold northerly air stream giving broken cumulonimbus clouds with snow showers. The altocumulus in which the lane was cut was almost certainly of the cumulogenitus type.

Sun pillar at West Raynham

The photograph of a sun pillar facing p. 145, was taken by Mr. J. D. Hastings at West Raynham, Norfolk, at 1630 G.M.T., January 21, 1950, using Ilford Pan. F. film and an exposure of one tenth sec. at F.2·9. The time of sunset was 1621 G.M.T.

The synoptic situation was as follows: on Saturday, January 21, 1949, a belt of high pressure extended from Scandinavia to the British Isles with two centres, one over south central Norway and the other off north-east England. A warm front at midday from the Danish-German border to an approximate position 58°N. 03°E. was making steady south-west progress, and by 1800 G.M.T. was lying from north-west Holland to about 58°N. 42°E. At 1500 G.M.T. medium cloud ahead of it had reached the coast of East Anglia and south-east England, altocumulus-altostratus was reported by Felixstowe, Manston and Lympne; Yarmouth reported altocumulus castellatus. Altocumulus-altostratus was reported by West Raynham in the 1600 G.M.T. observation. The Downham Market winds for 1400 G.M.T. gave directions and speeds of 70–80°, 15–20 kt. The warm front was in itself weak, but the arrival of warmer moister air in East Anglia just ahead of, and behind, it gave very bad weather during the night and the following day with fog, very low cloud and drizzle.

REVIEWS

The Geology of Water Supply, by Sir Cyril S. Fox. 10 in. × 6½ in., pp. x + 209. *Illus.* The Technical Press Ltd., London, 1949. Price 25*s.* 0*d.*

The book is one of a series planned by the Technical Press Ltd. to deal with hydrographic surveys for the storage of water resources, the treatment of water for purification and softening, the disposal of waste water and sewerage, and the erection of waterworks for towns. The author covers a wide field, including the

*See last paragraph of the article on "Artificial nucleation of clouds" by R. Frith, in the *Meteorological Magazine* for January, 1950, p. 9.

meteorological and geological factors affecting the availability of the water on the surface of the land or underground.

The book is well produced and sets out in simple language the fascinating details of the supply and disposal of water. It is a timely publication because of the present interest in water supply, arising in this country from the inconvenience of recent droughts and of catastrophic floods, as in the Tweed Valley in August 1948. It is a traveller's account of the subject, based on the author's thirty-six years' experience, mainly in India and Pakistan, so that many of the references to the literature are for places abroad, and some for not very recent dates.

The first five chapters deal with the subject from the aspect of general physical geography, the remaining four chapters are on surface water supplies, underground water supplies, engineering works and the quality of water. Of the nine chapters the second, " Rainfall considerations ", is concerned with meteorological aspects, the distribution of rainfall, the effects of marshes and forests, evaporation, percolation and absorption, yield of catchments, etc.

Adequately to cover so large a subject as rainfall in 31 pages is not easy, but a surprising selection of information has been given. A page has been devoted to the Beaufort scale of wind force, but the equivalent forces in miles per hour as given are not those now in general use (see the " Meteorological Observer's Handbook, 1942 "). The statement against Beaufort force 2 for winds at sea reads " Light breeze, 1 to 2 knots ", whereas the full specification of the Meteorological Office distinguishes between land, sea and coast, and for coast reads " Wind fills the sails of smacks which then travel at about 1–2 miles per hour." The equivalent velocities at a standard height of 33 ft. above open flat ground are 4–6 kt. or 4–7 m.p.h.

On p. 9 and p. 11 the author gives the annual rainfall over the land surface of the earth as roughly 30 in. It does not detract from the general argument, that there is a tremendous volume of rain, to find (in *Memoirs of the Royal Meteorological Society* No. 28 and the discussion) that the most recent determination is nearer 26 in.; the sea being much wetter with 47 in.

J. GLASSPOOLE

Statistisch Onderzoek naar de Samenhang Tussen het weer, de Grasproductie, en de Melkaanvoer. By Dr. Ir. J. Past. Koninklijk Nederlandsch Meteorologisch Instituut No. 102. Mededeelingen en Verhandelingen, Serie A, No. 55. $9\frac{1}{2}$ in. $\times 6\frac{3}{4}$ in., pp. 119. 's. Gravenhage, 1949. 3.00 florins. Dutch with English summary.

This publication is an account of the research carried out under the auspices of the Royal Meteorological Institute at De Bilt, into the statistical relations between weather, grass production and milk supply.

Important positive correlations were found between grass production, cloudiness and number of days with precipitation in May and June; similar correlations in July and August were found between milk production and these weather parameters. The temperature correlation was negative in this period.

The importance of this work was strikingly exemplified by the serious drop in milk production in Great Britain after the sunny dry summer of 1949, and again stresses the need for a correct distribution of available water for agricultural and urban needs.

L. P. SMITH

OBITUARY

It is with regret that we announce the death of Mr. and Mrs. John Bell Beck at the Observatory, Eskdalemuir, on March 8 and 10, 1950, respectively. Both were unexpected and occurred after very brief illnesses.

Mr. Beck joined the staff at the Observatory as a boy clerk in 1913, and it was not very long before he showed the qualities necessary for a good observer and recorder; he was careful, conscientious, painstaking and honest; indeed in 1919 he succeeded Mr. P. N. Skelton as chief magnetic observer, a post in which such qualities are essential.

During the last 30 years most of the magnetic work of the Observatory has largely been dependent on his skill and assiduity as an observer, and to him must be attributed a large part in the building up of the esteem with which Eskdalemuir magnetic work is regarded throughout the world.

Apart from a period of service with the army in The Royal Scots Fusiliers and the Cameron Highlanders in World War I and a visit towards the end of 1921 to Shetland to assist with the starting of magnetic observations at Lerwick Observatory, Mr. Beck spent all his service career at the Observatory, Eskdalemuir. Indeed, his long experience in all sides of Observatory work was of inestimable value to successive superintendents as he was the connecting link in the Observatory's history. His presence as such a link might have passed, as it were, without notice—his character being so unassuming—but his absence will be felt.

In private life, Mr. Beck took an active part in local affairs; he was an active supporter of the local branch of the British Legion; a keen bowler, and as a violinist or " fiddler " of no mean order was much in demand for local functions such as concerts and dances. His wife, also of a quiet and unassuming nature, played an unobtrusive part in local matters. They will be very much missed in the Valley of the Esk. Mr. and Mrs. Beck leave behind a son, William Robert, known to most as " Billy ".

METEOROLOGICAL OFFICE NEWS

Postings of assistants.—To many assistants, postings may appear to be made without any consideration for their wishes and domestic circumstances. This is far from being the real state of affairs, and assistants are invited to consider the reasons why postings cannot be avoided.

As a background to the problem it is necessary to remember that the total number of assistants required for the Meteorological Office is, at present, between 1,250 and 1,300. This establishment is deployed at 156 different units in the United Kingdom, 22 units overseas, and 4 Ocean Weather Ships, besides the three Headquarters locations in London, Harrow and Dunstable. Whenever a vacancy occurs at any of these units it is necessary to consider making a posting in order to maintain a strength which will suffice to meet the commitments of the State Meteorological Service. In most cases vacancies cannot be filled directly by the recruitment of new staff because of the length of training required.

The principal reasons why vacancies arise are :—

(1) Promotion of assistants,

(2) Call-up of assistants for National Service,

(3) Opening of new offices,
(4) Tours of duty in Ocean Weather Ships and overseas,
(5) Release of airmen from National Service,
(6) Resignation of assistants.

As far as possible all such vacancies are filled from a pool comprising :—

(1) Assistants reinstated on return from National Service,
(2) Airmen under training,
(3) Newly appointed assistants.

Assistants reinstated after National Service and newly appointed assistants who are under military age, are posted to units as close as possible to the location of their choice. If a vacancy occurs at a Royal Air Force station in a locality which is not amongst those selected by assistants in these two categories it is the general practice to post an airman. It thus comes about that airmen tend to be posted a little more frequently than their civilian counterparts. Generally speaking, less hardship is imposed on an airman by a posting than on a civilian assistant because airmen do not have to worry about finding accommodation at the new unit. But it would be a mistake for airmen to suppose that the frequency of posting to which they are subject whilst in uniform will continue when they are reinstated as civilians.

It is exceptional for postings of established assistants, other than on purely temporary duty, to be made for any but the following reasons :—

(1) To provide further experience and so improve prospects for promotion,
(2) To obtain promotion or special responsibility allowances,
(3) For study purposes,
(4) On request.

An intensive effort is being made, by forward planning, to avoid posting civilian assistants except for the reasons stated above, and at the same time to restrict postings of airmen to a minimum.

Prospects of promotion for assistants.—A question of great importance for every member of staff is : " What are my prospects in the Meteorological Office?" For assistants, many of whom are unestablished and whose minds are not yet firmly made up about the choice of a career, the answer to that question is vital.

Some recent letters of resignation suggest that assistants probably take too pessimistic a view of their chances of promotion from Assistant to Senior Assistant. At the present time there are sufficient posts to allow the promotion of every assistant whose experience and qualifications merit consideration : but it is realised that in the future the ratio of posts in the grades of Senior Assistant and Assistant will fail to provide sufficient opportunity to all those assistants whose qualifications are too restricted for them to enter the Experimental Officer class. For this reason plans have already been made to increase the ratio over the next few years.

It is quite exceptional to make a statement about staffing policy until it is possible to implement it. This information is given, however, because it is important that assistants should not be led to resign in ignorance of their prospects.

Ocean Weather Ships.—Dr. C. E. P. Brooks has kindly presented a travelling set of chessmen to the Ocean Weather Ships. The chess experts in the Ships are going to compete against each other for possession of this little trophy.

New Meteorological Observer's Handbook.—The present Meteorological Observer's Handbook was originally issued in 1908 as a successor to books of instruction written by Sir H. James (1851) and Dr. Scott (1875). The instructions for observing were brought up to date in successive editions, but no drastic changes in the general style and arrangement of the book have hitherto been made. The last edition appeared in 1939 and the need for revision became pressing after the Conference of Directors at Washington in 1947. It had also become evident that a re-arrangement of contents and considerable recasting was necessary to serve the varied needs of both climatological and synoptic stations. The Handbook has therefore been almost entirely rewritten and it is hoped that copies will soon be available for issue.

Courses for Meteorological Observers.—Four courses for Meteorological Observers were recently held at the Meteorological Office Training School. They were attended by Observers from Health Resort stations, Crop Weather stations and Climatological stations. The courses lasted for 2½ days and covered the making and recording of observations and the lay-out, care and maintenance of instruments. At the end of each course a visit was made to the Climatological Division at Harrow.

There is no doubt that both the Meteorological Office and the Observers themselves have much to gain from these courses and appreciation is due to the various authorities who made it possible for their observers to attend.

Sports activities.—Mr. W. C. Williams, Scientific Assistant at No. 1 (M.E.) Meteorological Unit, Ismailia, has captained the local R.A.F. team in another successful season.

Besides winning the Egypt Cup for the second season running, R.A.F. Ismailia have scored 169 points against 11 in their nine league matches : they lost only two friendly games, and one in the Canal North Cup. Mr. Williams plays scrum half, and is acknowledged to have a fine flair for the game.

THE WEATHER OF MARCH 1950

Mean pressure was slightly above 1020 mb. from Poland south-westwards across Germany, central and northern France, western Spain and Portugal to Madeira, and also between Bermuda and the Bahamas and over an area in Canada situated west of Hudson Bay and extending from about latitude 50°N. to 70°N. It was slightly below 1000 mb. over small areas between northern Norway and Spitzbergen and south of Greenland, and also over the Aleutian Islands. Departures from normal were not large ; there was an excess of 2 to 7 mb. over most of Europe and a deficit of about the same amount over most of the northern part of the North Atlantic west of about longitude 20°W.

Over the British Isles the weather was mild; it was dry except in an area extending northward from the Isle of Man and the Cumberland coast across Lanarkshire, in the neighbourhood of Skye and in a coastal belt in east Scotland.

In the opening days of the month pressure was high from Scandinavia to France, while troughs of low pressure moved north-east over the north-west districts of the British Isles; rain occurred, chiefly in the west and north (2·70 in. at Blaenau Festiniog, Merioneth on the 2nd), but it was bright, with frost early, in eastern and midland districts of England on the 1st. Gales occurred locally in the extreme north of Scotland on the 1st–4th. On the 4th the Azores anticyclone moved north-east and subsequently became established over southern England and central Europe; a period of fair, warm weather, apart from considerable fog night and morning, ensued. Day temperatures were high from the 5th or 6th to the 8th, reaching 60°F. locally, and touching 66°F. at Croydon on the 8th. On the 9th a shallow depression moved east-south-east across Scotland giving slight local rain.

Subsequently high pressure became established in a belt from Greenland to the Bay of Biscay, while a depression off west Norway moved south and then south-east. Mainly dry, colder weather prevailed in the British Isles, with local sleet or snow from about the 11th–14th; a screen minimum temperature of 18°F. was registered at Eskdalemuir on the 14th.

A change to a mild, unsettled type set in on the 14th, when a deep Atlantic depression moved east-north-east towards the west of Ireland and troughs of low pressure crossed the British Isles. The main centre eventually moved north-east to the neighbourhood of Thorshavn and another very deep depression in mid Atlantic moved slowly north-east; on the 17th a small secondary developed off south-west Ireland and moved quickly north-east across the British Isles and was associated with local thunderstorms. Throughout the period 14th–19th rain fell daily and was heavy locally, particularly in the north-west on the 18th (2·49 in. at Peden Reservoir, Lanarkshire, 2·25 in. at Ruthwell, Dumfriesshire and 2·20 in. at Borrowdale, Cumberland). Gales were registered at exposed places on the 16th–18th. From the 20th–23rd other shallow secondaries developed and crossed the country giving further rain at times.

Subsequently the Azores high moved north-east to the Baltic and later an anticyclone on the Atlantic moved to a position westward of the British Isles and a period of anticyclonic weather occurred, with morning fog. On the 30th and 31st shallow troughs moving south-east caused some slight rain in the northern half of the country.

The general character of the weather is shown by the following provisional figures :—

	Air Temperature			Rainfall		Sunshine
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ..	67	15	+3·7	60	−5	109
Scotland	65	17	+3·6	91	−3	96
Northern Ireland ..	62	26	+3·8	65	−6	111

RAINFALL OF MARCH 1950

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ..	·53	29	Glam.	Cardiff, Penylan ..	2·18	69
Kent	Folkestone, Cherry Gdn.	1·09	50	Pemb.	St. Ann's Head ..	2·35	66
"	Edenbridge, Falconhurst	1·39	56	Card.	Aberystwyth	1·50	55
Sussex	Compton, Compton Ho.	2·57	93	Radnor	Tyrmynydd	2·99	56
"	Worthing, Beach Ho.Pk.	1·23	64	Mont.	Lake Vyrnwy	3·34	74
Hants	Ventnor, Roy. Nat. Hos.	1·28	62	Mer.	Blaenau Festiniog ..	6·89	80
"	Bournemouth	1·35	58	Carn.	Llandudno	1·14	56
"	Sherborne St. John ..	1·18	53	Angl.	Llanerchymedd ..	2·75	93
Herts.	Royston, Therfield Rec.	·48	26	I. Man.	Douglas, Borough Cem.	3·54	120
Bucks.	Slough, Upton	·65	37	Wigtown	Port William, Monreith	2·83	99
Oxford	Oxford, Radcliffe ..	·87	53	Dumf.	Dumfries, Crichton R.I.	4·33	145
N'hant.	Wellingboro', Swanspool	·71	40	"	Eskdalemuir Obsy. ..	6·85	140
Essex	Shoeburyness	·58	43	Roxb.	Kelso, Floors	1·67	86
Suffolk	Campsea Ashe, High Ho.	·53	32	Peebles	Stobo Castle	3·57	123
"	Lowestoft Sec. School ..	·33	20	Berwick	Marchmont House ..	1·80	68
"	Bury St. Ed., Westley H.	·42	22	E. Loth.	North Berwick Res. ..	2·07	110
Norfolk	Sandringham Ho. Gdns.	·74	39	Midl'n.	Edinburgh, Blackf'd. H.	2·20	112
Wilts.	Bishops Cannings ..	·91	40	Lanark	Hamilton W. W., T'nhill	3·46	124
Dorset	Creech Grange.. ..	1·91	68	Ayr	Colmonell, Knockdolian	2·14	63
"	Beaminster, East St. ..	2·74	94	"	Glen Afton, Ayr San ..	3·80	90
Devon	Teignmouth, Den Gdns.	1·57	60	Bute	Rothesay, Ardencraig	3·31	92
"	Cullompton	2·08	76	Argyll	L. Sunart, Glenborrodale	4·51	81
"	Ilfracombe	2·08	72	"	Poltalloch	2·63	68
"	Okehampton, Uplands	2·83	68	"	Inveraray Castle ..	5·32	84
Cornwall	Bude, School House ..	1·40	57	"	Islay, Eallabus ..	2·36	62
"	Penzance, Morrab Gdns.	2·59	81	"	Tiree	3·35	100
"	St. Austell	2·46	72	Kinross	Loch Leven Sluice ..	2·97	99
"	Scilly, Tresco Abbey ..	1·61	61	Fife	Leuchars Airfield ..	2·39	123
Glos.	Cirencester	1·56	68	Perth	Loch Dhu	6·65	101
Salop.	Church Stretton ..	1·21	50	"	Crieff, Strathearn Hyd.		
"	Cheswardine Hall ..	1·51	71	"	Pitlochry, Fincastle ..	2·09	76
Worcs.	Malvern, Free Library	1·48	76	Angus	Montrose, Sunnyside ..	2·09	100
Warwick	Birmingham, Edgbaston	1·56	82	Aberd.	Braemar	2·27	76
Leics.	Thornton Reservoir ..	·86	47	"	Dyce, Craibstone ..	2·82	106
Lincs.	Boston, Skirbeck ..	·60	38	"	Fyvie Castle	3·61	133
"	Skegness, Marine Gdns.	·39	24	Moray	Gordon Castle	1·99	86
Notts.	Mansfield, Carr Bank ..	·98	47	Nairn	Nairn, Achareidh ..	1·19	65
Derby	Buxton, Terrace Slopes	2·47	60	Inverness	Loch Ness, Garthbeg ..	2·34	70
Ches.	Bidston Observatory ..	1·30	68	"	Glenquoich	7·98	82
Lancs.	Manchester, Whit. Park	1·82	81	"	Fort William, Teviot ..	5·69	85
"	Stonyhurst College ..	2·00	54	"	Skye, Duntuilm ..	5·32	121
"	Blackpool	1·64	69	R. & C.	Tain, Tarlogie House ..	1·03	46
Yorks.	Wakefield, Clarence Pk.	1·75	97	"	Inverbroom, Glackour..	3·45	69
"	Hull, Pearson Park ..	1·07	59	"	Applecross Gardens ..	5·06	109
"	Felixkirk, Mt. St. John	1·03	52	"	Achnashellach	6·18	91
"	York Museum	·98	58	"	Stornoway Airfield ..	3·44	88
"	Scarborough	·82	46	Suth.	Loch More, Achfary ..	5·97	93
"	Middlesbrough.. ..	·67	43	Caith.	Wick Airfield	2·61	115
"	Baldersdale, Hury Res.	1·52	49	Shetland	Lerwick Observatory ..	3·36	106
Nor'ld.	Newcastle, Leazes Pk. ..	·53	26	Ferm.	Crom Castle	2·43	78
"	Bellingham, High Green	1·26	43	Armagh	Armagh Observatory ..	1·08	46
"	Lilburn Tower Gdns. ..	1·11	42	Down	Seaforde	1·91	65
Cumb.	Geltsdale	2·21	79	Antrim	Aldergrove Airfield ..	1·31	52
"	Keswick, High Hill ..	3·77	84	"	Ballymena, Harryville..	1·86	59
"	Ravenglass, The Grove	4·10	133	L'derry	Garvagh, Moneydig ..	2·12	68
Mon.	Abergavenny, Larchfield	2·55	84	"	Londonderry, Creggan	2·31	72
Glam.	Ystalyfera, Wern House	4·83	90	Tyrone	Omagh, Edenfel ..	2·42	77

CLIMATOLOGICAL TABLE FOR THE BRITISH COMMONWEALTH, NOVEMBER 1949

Stations	Pressure		Temperatures							Relative humidity	Mean cloud amount	Precipitation		Bright Sunshine		
			Absolute		Mean values											
	Mean of day M.S.L.	Diff. from normal	Max.	Min.	Max.	Min.	½ Max. and Min.	Diff. from normal	Wet bulb			Total	Diff. from normal	Days	Daily mean	Percentage of possible
	mb.	mb.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	oktas	in.	in.		hr.	%
London, Kew Observatory	1008·3	−5·6	57	27	49·1	38·7	43·9	+0·1	41·5	90	5·9	2·16	−0·06	17	2·2	24
Gibraltar	1017·0	−1·0	84	46	68·8	56·2	62·5	+2·5	57·8	82	4·2	6·10	—	7	6·3	62
Malta	1013·9	−2·0	72	52	67·7	58·3	63·0	−0·9	59·5	70	4·6	4·74	—	15	6·9	68
St. Helena	1015·9	−0·6	69	53	64·3	54·4	59·3	+0·6	55·0	95	7·8	1·29	+0·05	15	—	—
Lungi, Sierra Leone	1011·7	—	89	71	86·4	73·5	79·9	—	75·2	87	5·9	4·49	—	9	7·1	—
Lagos, Nigeria ..	1010·5	+0·4	94	68	89·3	71·5	80·4	−1·3	78·4	85	6·6	2·92	—	8	7·0	59
Kaduna, Nigeria ..	1009·4	—	95	53	92·0	60·4	76·2	−1·7	63·8	37	3·9	0·00	−0·21	0	9·5	82
Chileka, Nyasaland	1012·1	−1·0	98	62	91·2	70·3	80·7	+3·0	67·5	54	3·5	1·60	−2·22	7	8·2	64
Lusaka, Rhodesia ..	1009·9	−0·2	101	62	88·4	65·8	77·1	+2·9	63·5	55	5·2	2·61	−1·62	15	7·1	55
Salisbury, Rhodesia	1011·0	−0·6	94	56	83·3	61·9	72·6	+2·4	61·1	53	4·0	2·54	−1·48	9	7·3	57
Cape Town	1015·0	−0·8	86	51	72·6	57·7	65·1	+0·7	55·9	60	3·8	1·23	+0·14	8	—	—
Palmietfontein, S. Africa	1011·7	—	88	45	76·4	54·2	65·3	—	56·6	64	4·0	6·83	—	13	8·6	—
Mauritius	1015·2	−0·9	90	59	84·7	66·0	75·3	−0·2	66·2	60	4·0	2·30	+0·54	12	8·8	68
Calcutta, Alipore Obsy	1013·3	−0·1	89	56	84·1	62·2	73·1	−0·4	65·2	62	1·0	0·00	−0·65	0	9·7	87
Bombay	1012·1	+0·1	94	69	90·3	71·9	81·1	+0·5	70·7	69	0·6	0·00	−0·45	0	10·2	91
Madras	1012·4	+1·1	89	66	85·2	71·4	78·3	−0·6	72·8	80	4·3	6·93	−6·68	7	8·9	77
Colombo, Ceylon ..	1010·7	+0·7	90	70	86·4	73·5	79·9	−0·1	74·9	84	4·2	9·70	−2·06	13	8·0	68
Singapore	1009·6	+0·2	91	72	85·9	74·3	80·1	−0·5	76·2	85	6·2	9·64	−0·27	16	4·3	36
Hongkong	1017·4	−0·2	85	55	74·9	65·8	70·3	+0·7	64·9	76	—	5·09	+3·35	10	6·1	55
Sydney, N.S.W. ..	1012·7	−1·1	90	50	73·7	60·2	66·9	−0·1	62·1	65	4·5	3·45	+0·60	11	8·1	58
Melbourne	1012·3	−2·1	85	46	69·1	52·0	60·5	−0·8	55·2	63	6·7	5·51	+3·28	17	4·5	32
Adelaide	1013·9	−1·4	94	42	71·1	54·1	62·6	−4·4	55·8	57	7·0	1·93	+0·79	13	5·3	38
Perth, W. Australia	1013·7	−1·7	96	50	76·6	56·8	66·7	+0·6	59·7	64	4·0	1·49	+0·69	10	8·7	63
Coolgardie	1013·1	−0·3	92	46	80·4	53·2	66·8	−3·9	58·6	55	3·4	1·74	+1·15	7	—	—
Brisbane	1013·8	−0·8	91	56	80·7	64·8	72·7	−0·8	65·2	65	4·4	4·52	+0·79	13	8·6	67
Hobart, Tasmania ..																
Wellington, N.Z. ..	1012·8	+0·8	71	41	61·8	48·6	55·2	−0·4	52·3	72	5·2	4·52	+1·00	11	7·0	49
Suva, Fiji	1011·0	−0·1	87	66	82·8	70·7	76·7	−0·4	72·7	82	5·7	9·22	−0·57	17	6·3	49
Apia, Samoa ..	1009·5	+0·4	89	71	87·0	73·5	80·3	+0·6	77·4	75	5·3	4·08	−6·30	18	7·5	59
Kingston, Jamaica ..	1012·5	+0·1	90	66	87·5	72·6	80·1	+0·8	74·1	77	4·0	3·02	−0·01	8	7·8	69
Grenada, W. Indies																
Toronto	1010·9	−6·4	62	5	42·6	31·9	37·3	+0·3	32·7	82	7·7	2·03	−0·60	11	2·5	26
Winnipeg	1011·8	−5·6	60	−5	36·7	24·0	30·3	+0·0	26·8	95	6·3	1·29	+0·22	12	2·9	32
St. John, N.B. ..	1010·5	−4·1	54	14	32·2	23·7	28·0	−1·2	25·6	90	6·0	8·21	+3·80	19	2·5	26
Victoria, B.C. ..	1015·7	−0·2	65	34	54·2	41·6	47·9	+3·4	44·8	92	7·0	8·74	+3·33	19	2·5	27